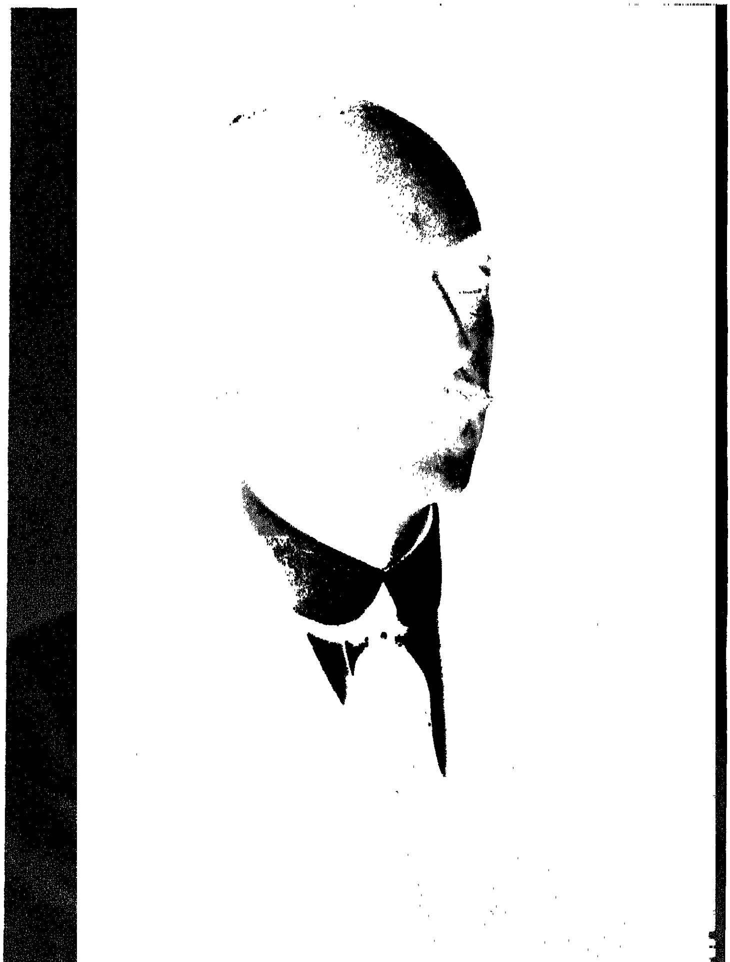

Photo by Lafayette

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RESEARCH

IN THE

COTTON INDUSTRY

A REVIEW OF THE WORK OF THE

BRITISH COTTON INDUSTRY RESEARCH ASSOCIATION

UP TO THE END OF 1926

CARRIED OUT UNDER THE DIRECTION OF

THE LATE

ARTHUR WILLIAM CROSSLEY

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EDITED BY

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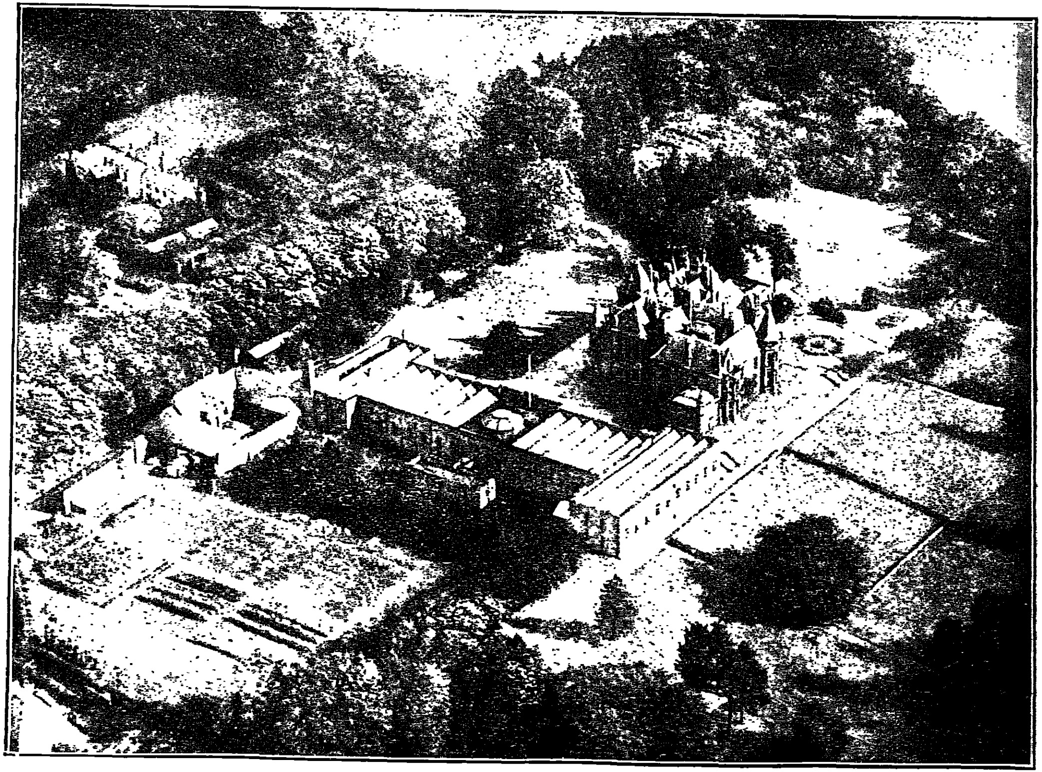

Aerial view of the Shirley Institute showing at the southern end the block containing the Machinery Room and Testing Department.

FOREWORD.

This report is intended to enable members of The British Cotton Industry Research Association to form an opinion of its progress during the first five years in which research work has been actively prosecuted in the Shirley Institute. Although in this period up to the end of 1926 some 130 memoirs have been issued, such is the organised sub-division of the British Cotton Trade that few members will be in a position to assess the value of all the information—some of it of a highly abstruse scientific character—therein contained. In the following pages an account under various headings is given, in words as free from scientific terms as possible, of the main topics of the published research work. It will be seen that this has dealt with nearly all sections of the trade; results have emerged more quickly in some directions, inevitably so, but the relative amount—much less their value—in no sense indicates the time and energy which have been devoted to the different sections. This statement particularly applies to the processes of spinning and weaving, as only some of the problems on the mechanical side of these oldest and fundamental sections have seemed suitable for a frontal attack.

The value of the work done is by no means completely represented by the published results—in several other ways the Shirley Institute has been of use. The so-called negative result obtained when it has been found that an existing process is scientifically sound is really of considerable value, although financially only indirectly so and is frequently a necessary step to future development. The rapid and certain diagnosis of perplexing faults in cotton goods, which in so many instances can be made for members by the staff of the Institute, is of vital importance to this industry in which many have of necessity little knowledge of the methods of the processes which precede or succeed their own.

The numerous day to day consultations between the staff and members, the insistent demands for lectures by the staff from all the cotton towns and the popularity of the Saturday afternoon exhibitions are all further evidence of the great value which the Industry attaches to the work of the Institute.

The Industry may well be proud of its Research Association. The building up of this organisation, characterised by the variety and competence of its staff, the extent of its scientific equipment and the scope of its library and information bureau, required a tremendous effort. The whole organisation is a constant reminder of the genius of its first Director of Research,

ARTHUR WILLIAM CROSSLEY.

To him are largely due the results which are herein described and the abundant promise of those to come.

ROBERT H. PICKARD,
Director of Research.

British Cotton Industry Research Association,
Shirley Institute,
Autumn, 1927.

INTRODUCTION.

Though the main work of the Association has followed a definite programme of research covering all sections of the industry, it has been inevitable that much time has been spent in considering day to day difficulties arising in industrial practice. It is better to discuss this work before that of the general research work, since an adequate idea of the practical value of scientific research is most easily conveyed by examples of its application.

Many of the difficulties encountered during spinning, manufacturing and finishing can be met by the practical man on the spot or elucidated by existing methods in official testing laboratories. It is no part of the work of the Institute to undertake straightforward testing of materials or to examine defects due to causes which are well understood. On the other hand, where damage or difficulty arises in an unaccountable or unusual way, it is clearly desirable that the scientific resources of the Institute should be employed to analyse the cause of the trouble so that the industry as a whole may be advised how best to avoid its recurrence.

Several hundred of these special investigations have been carried out during the period under review and it has been found that in many cases the results are of wide interest. The scope of this branch of the Association's activities will perhaps be best indicated by a description of some typical examples in which new methods of attack, developed in the course of research, have proved of assistance.

The Raw Material.

The methods of identifying cottons outlined in Chapter I. have been used successfully to determine the type of cotton employed in the manufacture of particular yarns or cloth, and to elucidate the causes of certain faults in bleached and dyed fabrics. In one instance, the

cotton from which a very attractive soft spun yarn had been made was identified by hair weight per centimetre and staple length measurements. In another, a distinct bar, about one cop in width, which ran across the full width of a piece of grey cloth was shown by measurements of hair weight per centimetre and hair width to be due to the accidental use of a cop of different yarn.

Similarly, the differences in lustre and shade between two poplins after mercerising and dyeing were traced to the use of different cottons in the weft yarns. It is not, of course, in every case that the methods enable so definite a statement to be made, for difficulties arise when the yarn is spun from a mixture of two or more varieties.

As a direct consequence of the critical examination of specimens submitted by many firms, it has been discovered that brown staining of cotton yarn may arise from infection of the conditioning water with bacteria which when taken up by the yarn in sufficient quantity produce a coloured deposit. An appropriate antiseptic has been prescribed to stop this action, and is now used by many firms. A more general solution of such problems arising out of conditioning is dealt with in Chapter II.

Some chemical tests which at first sight appear to be of interest solely to the bleacher and finisher occasionally prove of value in connection with a definite requirement of the spinner or manufacturer. Methods of analysis have for example been used in testing samples of cotton for the presence of mineral oil which it was suspected had been sprayed on to the cotton prior to baling. In one case, the suspicion arose because the feel and pull of the sample were different from those of cottons of the same mark and grade customarily used in the mill, but the cause was found in the natural wax content of the material, which was significantly higher than that of the cottons with which the spinner was comparing it. Another interesting example of the application of chemical analysis is the following. The uppers of canvas shoes are commonly made from grey cloth woven without size,

and this is submitted to dry heat during the vulcanisation of the rubber soles. A darkening in shade is thus caused which may be so pronounced as to render the cloth unsuitable for the purpose, even when American cotton of the same grade is invariably employed. The origin of this variation was traced by means of chemical measurements which are described in Chapter I. and which enabled the most suitable cottons to be readily selected.

Spinning and Manufacturing.

The frequent use of sorting tests for judging the staple of cotton (see Chapter I) has provided the basis for a definite opinion in the analysis of a cloth, when the question at issue was whether both warp and weft had been spun from combed Sakel cotton. The yarns were pulled down and the fibre sorted by the Baer instrument, and the appearance of the "staple diagram" was easily identified as characteristic of combed Sakel. Continuous tests for yarn regularity as described in Chapter II. have explained an effect known as "steepling" which marred the appearance of certain cloths woven with mule weft. In one case the weft was found to have short sections with high twist at regular intervals, the distance between these points coinciding with the length of the mule draw. As these intervals were almost exactly twice the width of the cloth, the high-twisted sections were falling together in the cloth, thus giving the "barred" effect. The spinner was advised to employ a different mule stretch and the trouble was overcome. Another case of a cloth showing different degrees of light and shade when viewed across the width was suspected in the mill to be due to uneven running of the mule spindle, leading to irregular twists, when spinning the weft. A new method of measuring twists per inch on consecutive short pieces, showed that the yarn on the cop was too regular to have caused the trouble, and the defect was traced to irregular picking in the loom.

Cotton is exposed to damage by mildew at so many stages from the grower to the ultimate user that manufacturers will readily appreciate the reason why a section

of the staff is engaged in the search for a more satisfactory antiseptic than zinc chloride. Mildewed goods have been examined on many occasions, and the advice given has been appreciated. The investigations have greatly assisted the work on the mildew problem by making it possible to select a small group of mildew fungi which represent not only the most prevalent forms but those most resistant to antiseptics. This selection is now used in testing antiseptics (see Chapter III).

A number of examples of irregular behaviour during or subsequent to weaving have been traced to the amount or nature of the size employed, and cases of bad weaving and harsh feel have been shown to originate in an unduly high percentage of size on the warps in question. A microscopic technique developed for research purposes was successful in determining the exact manufacturing processes employed in the production of a special fabric of foreign origin, whilst to meet the difficulties of another member an investigation of the sizing of bleached warps was carried out with the object of discovering how best to secure the maximum whiteness of the floating threads in a particular weave. For this purpose the laboratory tape frame was employed in a series of small scale experiments, the results of which enabled the manufacturer to produce a cloth superior in appearance to anything previously obtained. A number of cases of defective dyeing or finishing have proved to originate in variable or excessive sizing, and the three examples which follow afford an effective demonstration of the troubles which must often arise in bleaching and finishing from these causes. The first shows the effect of variable sizing over one sett of warps; the second that of variation in the sizing practice of two manufacturers producing the same stock fabric; the third that of excessive sizing.

In the first of them the cloth had been fully bleached and stiffened by calendering without the addition of any filling but it appeared technically impossible to obtain a uniform finish throughout one delivery of pieces which all came from the same manufacturer and were supposed to be identical. The investigation proved that the handle

of the bleached pieces varied in a regular manner with their fat contents, and as they had been bleached together it was suggested that the cause would be found in variable sizing. This proved to be the case, the grey weights of the pieces, supposedly identical, varying from 34 to 37 lbs., and the size contents from 6 to 13 per cent, with corresponding variations in the amounts of fat. On enquiry, it was found that the variations had arisen from the admixture of the remainder of a heavy size with the fresh charge of pure size for the bleached cloth. A second example of trouble caused by variable sizing occured in a batch of low sateens which were schreinered after being bleached, dyed and back-filled. The grey cloth proved to have been woven by two manufacturers, one of whom used a light size and the other a heavier mixing containing china clay, the size contents of the cloths thus ranging from 5 to 14 per cent, and the fat contents showing consequent variations. The bleaching process, although adequate for the lighter sized pieces, effected only a partial and irregular removal of sizing fat from the heavier sized, the irregularity displaying itself as warp-way streaks in the finished pieces. In a third case, samples of a printed cloth with a tinted background were submitted in which the backgrounds were blotchy and irregular. The cause of this was traced to the excessive amount of fat present in the grey state, due primarily to excessive sizing, and a lighter mixing was recommended which prevented recurrence of the trouble.

Bleaching, Dyeing and Finishing.

Bleaching has proved responsible for loss in strength of material in a number of cases, and the utility of the methods described in Chapter IV. has been well tested. Experience has shown that the loss of strength which forms the subject of complaint is not infrequently the cumulative result of a number of processes, chemical and mechanical, each contributing something to the ultimate damage. Fabrics have been examined, for example, in which it was claimed that the selvedge was tender whilst the body of the cloth was not, but in which examination

proved that the whole fabric had suffered considerable loss in strength from chemical causes. The severer mechanical treatment to which the borders of cloth are frequently submitted may result in a local break-down which would not have occurred in the absence of such general tendering. This experience justifies the Association in condemning those bleaching processes which, though they do not appear to tender the cloth when judged by the rough and ready "finger and thumb" test, may yet cause a 10 to 20 per cent. loss of strength.

One or two examples of particular interest have been encountered in which, although the conditions of bleaching were perfectly normal, the presence of iron in the cloth greatly energized the bleaching liquor and resulted in intense local tendering. It cannot be too strongly emphasised that iron, either in the form of rust stains or mixed with oil in the form of machinery abrasions, is a potential cause of tendering during the bleaching process.

In a few cases examined, improper "condition" of the bleach liquor has been established as the cause of disturbing changes in the shade of fast coloured stripes.

Irregularities due to local excesses of fat have been a frequent subject on which the opinion of the Association has been invited. The standard methods of fat analysis have been so refined that even when the weight of fatty matter which can be obtained from a fabric is no more than one grain it is possible to give some opinion as to its quality. In many cases, however, the faults were too small or ill-defined to allow the successful use of even these delicate methods, and the necessity for some rapid staining test for the presence of oil or fat which would also show how it was distributed on the surface of the material became evident. By the test devised it has been possible, for example, to show that local variations in shade in a poplin cloth dyed ecru style originated in the "spotting" of dirty mineral oil stains with a vegetable oil to assist their removal during bleaching, the more precise analytical methods indicating that olive oil had been used. In another example a sateen which had been dyed, back-filled and schreinered showed streaks which were

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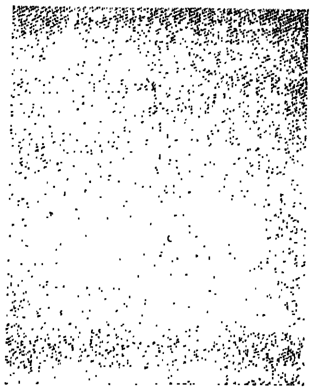

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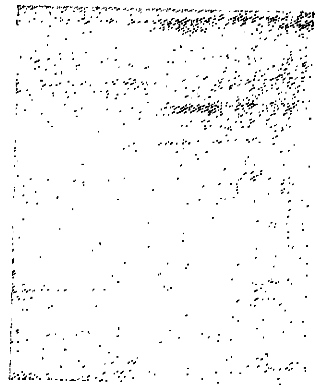

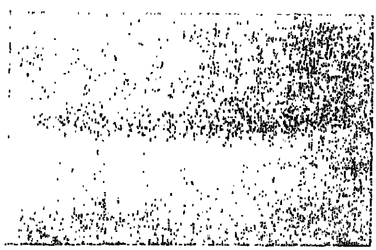

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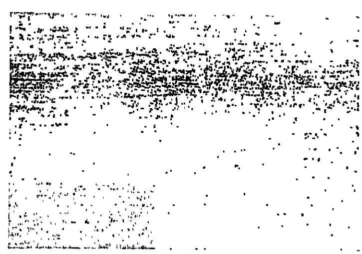


4.

Fig. 1. Streaks in khaki drill due to irregular distribution of cotton wax after a light bleach. The grey cloth was sized without fat.

Fig. 2. The same cloth with the colour discharged and the streaks made more obvious by means of a special dye.

Fig. 3. Local dark patch in cloth dyed with Thional Brown. Caused by excessive rubbing in removing an oil stain from the grey cloth.

Fig. 4. Local excess of tallow in a lightly bleached cloth shown up by staining with a special dye. The fault was caused by greasing a rough warp and when the bleached cloth was dyed, back-filled and schreinered it gave rise to a similar irregularity.

not evident in the bleached or dyed state. Staining tests on the bleached material revealed well-defined bands of fat which probably originated in the greasing of a rough warp. In this and in many other cases, it has been found that an amount of oil or wax which causes no evident defect in the bleached or dyed state often becomes very evident after the goods have been schreinered or hot calendered. Less commonly, whole pieces have proved defective, owing to insufficient scouring. An interesting example was found in a khaki drill, streakiness in which was due solely to the irregular distribution of the residual cotton wax, since the size was free from fat and wax.

About one quarter of the faults examined have manifested themselves as general unlevelness or periodic irregularities in the shade of dyed goods. Perhaps more than any other process, dyeing demands for its successful performance a maximum regularity in all mill and works operations and it can safely be said that the majority of faults which eventually appear as dyeing defects originate at some earlier stage. Unsuitable raw cotton, irregularities in the counts or twists of yarns, variations in sizing or weaving, improper treatment of cloth for the removal of stains, inefficient desizing, insufficient boiling, over-bleaching and irregular mercerisation have all been definitely traced as sources of dyeing defects submitted for examination by members. Thus every branch of the industry, even from the cotton grower, can still contribute to the production of more perfect dyed goods, and it is to this end that the advantages of the great variety of experience, methods and technique at the Association's disposal become most evident.

No example has yet been encountered in which the mixing of different marks or varieties of cotton during the spinning process has resulted in unlevel dyeing, but among the defects submitted a certain number have been traced to the mixture, in manufactured goods, of yarns spun from different varieties, and the methods of identification described in Chapter I. have proved extremely valuable in establishing this source of irregularity. The commonest dyeing defect which can be traced back to the

raw material is due to the presence of "dead" or immature cotton, and very many such samples have been received and diagnosed. It is now possible to determine with certainty from microscopical and chemical examination whether a dyeing fault is or is not due to the presence of "dead" cotton. The use of certain dyes or of certain finishing processes greatly reduces the unfavourable dyeing properties of dead cotton, but the necessity imposed upon the dyer of working to price, shade, and finish generally renders it impossible for him to cover the defect. The only remedy then lies in improving the the quality of the raw material or increasing the efficiency of spinning. It may be of interest to note that the Association's records show a periodic recrudesence of "dead" cotton defects in the spring and autumn months.

Another trouble which goes back to the bale is the presence of an undue amount of fuzz, and just as the thin-walled "dead" cotton usually appears in the form of light specks, the thick walled fuzz appears in the form of dark specks.

One of the commonest sources of dyeing faults is undoubtedly the mercerisation process. Very many examples have been investigated particularly for the hosiery trade, in which variations occurring during hank mercerisation have resulted in abrupt changes in shade. It is usually possible to establish mercerisation as the source of the trouble, but it is often extremely difficult to locate the exact point at which the defect arises. At present, it can only be said that yarn mercerisation is among the most difficult of processes to control, that very slight variations in conditions have a serious effect on subsequent dyeing, and that manufacturers would be well advised to make certain that different batches of mercerised yarn are never mixed in the same goods.

The foregoing represent instances in which immediately recognisable results have followed from scientific enquiry into the operations of the cotton industry. In the following chapters the methods of approach to some of the major problems of the industry are dissected. This

introduction has dealt with details,—some vital, some merely incidental; the report itself deals with principles.

The Association proposes to continue to carry out special investigations on the lines just described. Naturally as the methods of examination developed at the Institute become routine in their nature they will come increasingly within the scope of the official and private testing laboratories, so that there will be a gradual tendency for much of this work which has been done at the Institute to be passed on to other organisations. Members may, however, feel assured that their enquiries on points of individual interest will continue to be welcomed as these aid the applications of the results described in the Memoirs.

CHAPTER I.

Characterisation of Cottons by Means of Physical and Chemical Tests.

Cotton spinners and manufacturers have long been conscious of a serious difficulty in expressing their needs to the growers, who have often been disappointed to find that what they had hoped to be a useful cotton met with little appreciation by the user. Such a difficulty can be overcome by determining what exactly are the properties of a raw cotton which make it valuable in spinning and manufacturing, and devising means for measuring these properties so that growers and users can meet on common ground.

A necessary preliminary has been the establishment of methods for measuring any character of raw cotton which can be numerically expressed.

Measurable Characters.

Staple Length.—In many instances use has been made of the Baer sorter and the Balls sledge sorter for testing the staple of cotton. A modification of the latter instrument has been employed for the more recent critical work; with this the actual number of hairs of a given staple length is obtained instead of the weight as with the original type, thus dispensing with the need for a very sensitive balance. Mechanical methods for determining staple suffer, unfortunately, from the disadvantage that the cotton must first be well carded and drawn. Provided, however, that the cotton is in this form, it is possible to measure the staple more quickly with much simpler appliances, but with results which are nearly as trustworthy as those given by the Sledge Sorter. An account of two such simple methods has been published and in response to inquiries a suitable instrument for use in the mill has recently been produced (see p. 68) but as

even this deals with a drawn sliver it is still necessary to determine the amount and character of the loss prior to the carding process.

"Fineness." Some measure of the fineness or coarseness of the average hair in a sample of cotton might be expected to prove very valuable. The area of cross-section, for example, supplies the kind of information suggested, but, unfortunately, measurements on cross-sections involve too much labour for use in the mill. A simple observation of width would also serve the purpose, but owing to the convolutions in the hair such direct measurements take much time. If the cotton is immersed in 18 per cent. caustic soda, however, the convolutions disappear and the hair becomes an almost regular cylinder, so that it is now much more easy to measure the width. This is done after washing and drying the swollen hair and the "mercerised diameter" for the sample is the average of a number of such observations made near the middle of the hairs. The dimension bears approximately the same ratio to the diameter of the unmercerised hair for all varieties of cotton, and, moreover, it is directly related to the diameter of the fully grown hair in the boll before bursting. It is justifiable, therefore, to compare the fineness of cottons by means of this "mercerised diameter."

Hair weight per centimetre. The "mercerised diameter" is directly related to another quantity—the "hair weight per centimetre"—which is now almost exclusively used in routine tests on cotton. The measurement is made as follows:—Four small sample tufts of the cotton under examination are prepared and combed out, and a portion is cut from each tuft exactly one centimetre long. Fifty cut hairs are then counted out at random from each tuft, rolled together, and weighed on a micro-balance. The values of the "hair weight per centimetre" so obtained have been recorded for 127 sorts of cotton and it has been shown that a determination of this figure is often useful in deciding what type of cotton has been used in a particular fabric.

Chemical Methods for the Identification of Cottons.

When work was begun in the laboratories it was not known whether varieties of cotton which differed in botanical or geographical origin and in spinning properties could also be distinguished in chemical composition. Raw cotton freed from mechanical impurities contains, apart from its natural moisture, about 90 per cent. of cotton cellulose and any chemical differences between different varieties of cotton must be confined to the residual 10 per cent. of non-cellulosic substances. Certain regularities have been observed in the composition of this residual material which are of assistance in the identification of raw cottons. Egyptian varieties contain, for example, roughly twice as much chemically combined phosphorus as normal American varieties and although the maximum amount ever found in a clean raw cotton is about 0.1 per cent., so persistent is this difference that it seems possible to distinguish with certainty between Egyptian and American cottons by chemical analysis, although the test is slightly less emphatic when applied to cotton from combed yarns. Sea Island and South American cottons fall between the Egyptian and American varieties with respect to their phosphorus content, whilst Indian cottons are extremely variable, so that it may frequently be impossible to define with certainty the origin of a given sample when no other information is available.

Raw cotton contains as a maximum about 0.4 per cent. of chemically combined nitrogen—a much greater percentage than the maximum phosphorus content—but the differences in the amount of nitrogen in the common varieties are relatively smaller and although Egyptian cottons contain appreciably more nitrogen than American varieties, its determination is not very suitable as an identification test. The wax content of raw cotton, which varies roughly between the extremes 0.3 per cent. and 0.6 per cent. and tends to be higher the finer the cotton, affords little assistance in identifying the origin of the material but the actual nature of the wax is very characteristic in one particular group of

cottons. Wax obtained from native Indian growths possesses certain chemical properties such as higher acid, saponification, and iodine values (see p. 35) than those of other cottons, which renders the chemical identification of Indian cottons a comparatively simple matter.

Raw cotton also contains a group of substances in small quantities which cannot be very closely defined but which show chemical similarity to dextrins and sugars. These substances presumably participate in the life history of the cotton hair. They are described chemically as "reducing substances," and their amount can be determined by a measurement known as the copper number of the cotton (see also p. 54). With but few exceptions the copper number of Indian cottons is much higher than that of other growths, a fact which can be used as a confirmatory identification test.

On the other hand, the amount of mineral ash given by Indian varieties cannot be used for their identification as has been suggested by earlier workers.

It was to be expected that the chemical composition of any particular variety of cotton would vary from crop to crop with the soil, climate and plant environment, and it has been shown from a series of analyses made on pure strain cottons grown under controlled conditions that such factors do exert definite specific, but small, effects upon the phosphorus content of the lint. These variations are, however, small when compared with the differences between two such varieties as Egyptian and American. During the last six years the crops of Sakel and Texas cotton have not varied greatly in phosphorus content, the difference between the two remaining each year substantially unaltered. It is interesting to note, in this connection, that Pima cotton, an "Egyptian" variety grown in America, is abnormal in all its chemical properties when compared with other American growths and in phosphorus content it remains characteristically Egyptian. Apart from this, the long staple American varieties resemble Sea Island in a number of their chemical properties,

The chief advantage of the chemical method of identification lies in the fact that it avoids the necessity for making the very large number of observations which the great variability of the material imposes upon accurate determinations of single hair characters. If methods of chemical analysis could be sufficiently refined, a variability would undoubtedly be found in the chemical composition of the single hairs similar to that now found in their measurable characters and it can be shown that any chemical measurement obtained by analysing a sample of cotton is merely the average of a large number of different values corresponding to different hairs or groups of hairs in the sample. When cotton which has already been freed from mechanical impurities by carding is combed, the comber waste, which contains the relatively short hairs, possesses a different chemical composition from the combed sliver, which contains the longer hairs. The copper number, the phosphorus, nitrogen and wax contents of, and the mineral ash given by, the shorter hairs in the comber waste are much greater than the values for the corresponding longer hairs of the combed sliver. In spite of this variation within the material, single analyses generally yield accurately representative values for the chemical properties of a given cotton variety when it has been carded, thus showing that the size of a sample taken for chemical analysis is sufficient to ensure automatically that careful sampling and statistical averaging which is an essential feature of work on single hairs.

The chemical differences between raw cottons which enable certain conclusions to be drawn regarding their origin disappear almost entirely after bleaching, one of the objects of this process being to produce as pure a cotton cellulose as possible and to eliminate those extraneous substances upon the presence of which the differentiation of raw cotton depends. The only chemical method available for the identification of bleached cottons is the determination of the amount of the dyestuff methylene blue absorbed by them (see p. 54). The absorption of methylene blue by Egyptian cotton is

higher than that by American cotton *bleached in the same process,* whilst native Indian cottons are characterised by still higher absorption values.

Indian grown cottons of American origin, such as Cambodia and Punjaub-American, resemble in this respect the normal American varieties, yielding very much lower values for methylene blue absorption than the native Indian cottons. This method would prove of great value in identifying bleached cottons but for the fact that the absorption of methylene blue is determined not only by the variety of the cotton but also by the exact nature of the bleaching process. Although American cotton always possesses a lower absorption than Egyptian when the two are bleached together, it is yet possible for a mildly bleached American cotton to show a higher absorption than a severely bleached Egyptian sample. Since in general the conditions of bleaching are unknown, this fact very greatly limits the utility of the measurement considered as an identification test.

As a summary of the progress made in this branch of the work it may be said that very definite and characteristic chemical differences have been shown to exist between raw cottons of different varieties and that in certain cases the results of chemical analyses may be used with great advantage as additional or confirmatory tests for their identification. In very few cases, however, is it possible to identify the particular growth by chemical methods after the cotton has been scoured, bleached, or dyed.

It has been suggested in the past that Indian cotton has a higher, and American a lower moisture regain than Egyptian, and that the regain measurement could therefore serve as a distinguishing test. This is not so. The differences among raw cottons are too small for this purpose and almost disappear when the cottons are cleansed by boiling with water.

CHAPTER II.

RESEARCHES ON SPINNING AND DOUBLING.

It has always been the object of the spinner to obtain the greatest possible degree of regularity in his cotton material at each stage of the process in order to obtain that regularity in the final product which distinguishes the highest quality of yarn. The ideal—though unattainable—lap, card sliver, drawn sliver, or roving, would always be the same weight per yard or per inch throughout its length, and obviously the best way of testing and of improving this regularity is by examining the product of each machine. The work of the Institute under this section has been largely, if not mainly, in the direction thus indicated, though many other factors have to be considered also, such as staple length, cleanliness, regularity of twist, speed of production, and other economic considerations.

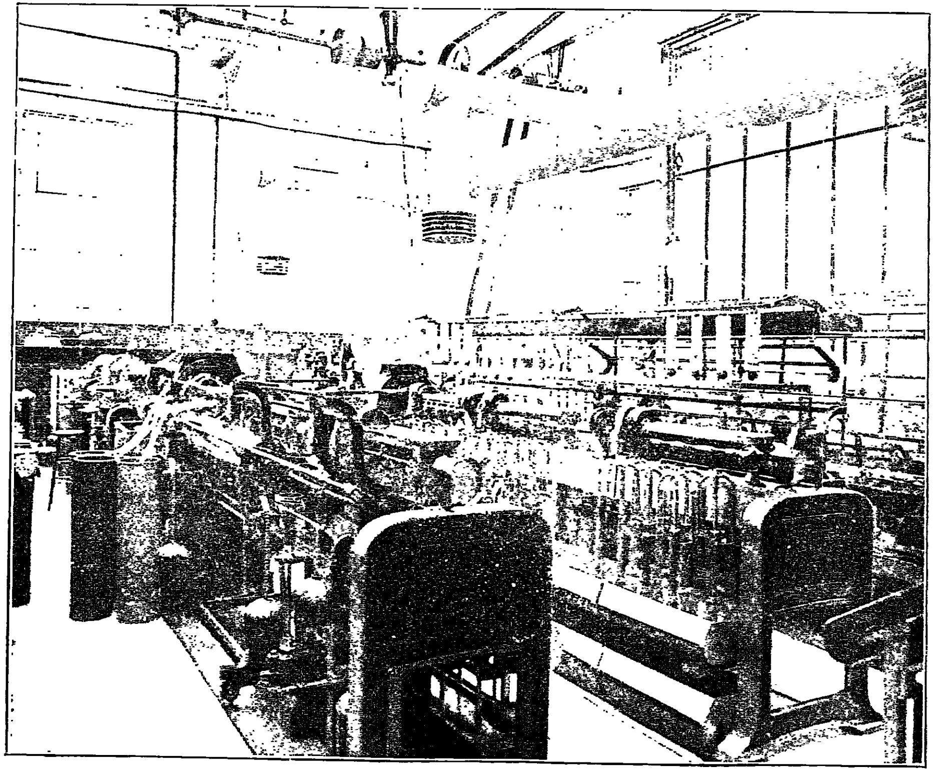
An exhaustive study of the carding process has been made and a comprehensive report will eventually be published. Some indication of the trend of the conclusions drawn may be gathered from the specification of a modified carding engine for which Letters Patent have been granted to the Association (E.P. 237013) and from the design of a simplified carding engine covered by the Patent specification E.P. 268511. It is claimed that this simplified card for equal rates of production yields as good a quality sliver as the ordinary standard card but has the advantages that it is smaller than the standard card and should be cheaper since it has only a 40 in. instead of a 50 in. cylinder and a greatly reduced number of flats, out of which only 13 are actually working instead of the usual 46. Cost of upkeep and running are therefore both smaller whilst the initial cost and the space occupied are less than that required by the standard machine.

The work on the mechanism of the carding engine, the modified and simplified cards, is complete as regards laboratory tests and the simplified card is now undergoing extensive mill trials on American and Sakel cottons. As far as these trials have progressed on American cotton, they have proved satisfactory under mill conditions of production.

The measurement of the regularity of card sliver has, in conjunction with the new theory of the mechanism of carding, led to the disclosure of considerable local irregularities in finisher scutcher laps, irregularities which have been directly confirmed on the lap regularity tester. The work on the card is therefore now being extended to investigate the mechanism of the earlier processes of scutching and blow room machinery in general.

With the new sliver regularity and impact testers now available (p. 69) the regularity of carded and combed slivers and of the slivers from each head of drawing has been examined and numerous measurements have been obtained of the increased regularity of hank number produced at the draw frames and of the degree of parallelisation produced by the comber and the draw frames.

A large number of experiments have been made on high drafting on the slubbing, intermediate and roving frames. Investigations on the regularity of hank number (on the sliver and roving regularity tester) and of cohesion (on the impact tester; see p. 70) of the card room products spun in various mills and in the machine room at the Shirley Institute, have to some extent indicated that the speed frame products are less regular than the sliver from the third head of drawing. (Actual measurements of sliver, roving and yarn properties which illustrate this decrease in regularity are given in the later section on High Drafting). It has been shown further that the regularity of high draft yarns is not impaired by the fact that the roving frame has been left out in certain of the systems examined, and since therefore a doubling has been sacrificed it became



A corner of the machinery room.

apparent that high drafting on the speed frames might be successfully accomplished. The work as it stands has given promising results and high drafts have been satisfactorily obtained at the Institute with Sakel, American and Indian cottons, and the yarns spun from the rovings so produced, either with high or normal drafts at the ring frame, are as good in quality and strength as those produced with normal low drafts on all the speed frames.

Opening Processes—Effect on Staple Length.

The question as to how far the staple length of cotton is reduced by the usual opening processes has been investigated for American, Queensland, Sakellaridis and Sea Island cottons. The results indicate that when due allowance is made for experimental difficulties—which is particularly necessary with Sea Island cotton—the mean staple length of the cottons employed was not affected by the particular opening processes examined, nor were the hairs weakened appreciably.

As the ordinary opening processes proved to have little or no effect on the staple length of cotton, the investigation was extended to examine the effect of excessive scutching beyond that normally practised in the mill. The staple lengths of samples of Indian, American, Sakellaridis and Sea Island cottons which were scutched up to four or five times more than is usual were found to be identical with those of normally scutched samples. Further, the yarns which were spun from the Sakellaridis and Sea Island cottons were equal in breaking load and regularity to yarns of equal count spun from the normally scutched cottons. (As the finer cottons proved to have been damaged no more by repeated scutching than by the usual treatment, it was considered unnecessary to complete the tests on Indian and American cottons.) It is not suggested that this degree of over-scutching is advisable but it appears certain that if, for the purpose of cleanliness, a moderate amount of extra scutching is considered necessary, there would apparently be little danger of this treatment affecting the strength or

regularity of the resulting yarn. These well-substantiated experimental results are contrary to the views of some spinners.

Yarn Regularity.

The regularity or evenness of yarns is a property of fundamental importance. It implies a more regular woven or knitted fabric, accompanied by a greater uniformity of finish whether the fabric be afterwards dyed, mercerised, calendered or schreinered, etc. No finishing process can eradicate the effects arising from irregular distribution of counts and twist and no system of doubling can achieve uniform doubling twist if the singles themselves are irregular. The bearing of regularity of twist and counts on barring or steepling in fabrics and on the lustre of folded yarns and of schreinered fabrics indicates how important to some sections of the cotton trade is the spinning of a regular yarn.

Methods of Testing. (a) The regularity of the thickness under compression in single yarns, varying in counts from 20's to 240's, has been recorded photographically on the yarn regularity tester (p. 69) by drawing the yarns between a pair of case-hardened steel shoes, the motion of the top shoe recording under high magnification on a strip of photographic paper the variation of thickness. Direct evidence of a periodicity of thickness, in other words the regular occurrence of thick and thin places, has been obtained in all mule yarns so far examined, the length of the period, corresponding with the stretch of the mule, being determined by the intermittent action of the mule mechanism. The portion of roving delivered to the spindle tip when the carriage has run in is preferentially treated, the twist being, at the end of the subsequent stretch, a maximum at the spindle tip. It might be expected that during the process of "backing off," some of the excessive twist near the spindle tip would be transmitted to the length of yarn of low twist released from the spindle, and probably this

is the case to some extent, but the action of the counter and winder faller wires in taking up the length of yarn "backed off" will tend, by the pressure they exert on the yarn, to prevent this, and this portion of the yarn is wound on the cop before the pressure is relaxed. The length of the yarn released from the spindle during backing off will therefore have a lower twist than the adjacent portion in the stretch near the spindle, for during the previous stretch the former length was near the delivery rollers where the transmitted twist was low. This relatively high twist in the stretch near the spindle exists whether there is roller delivery motion or not. On account of the difference in twist between these two portions of yarn the photographic records clearly show where the operation of "backing off" took place. Ring yarns do not show any periodic effect and this is in keeping with the continuous nature of the ring spinning process, no element of roving being preferentially treated. Irregularities of the roving produce only random irregularities in the yarn spun by either the mule or the ring frame, but they are more pronounced in ring spinning since the long steady stretch of the mule effects equalisations of twist and roving variations which do not take place on the ring frame. The photographic method of testing has the advantage that it is continuous, rapid, automatic and capable of high magnification, and gives permanent records, whilst the yarn being still undamaged is available for other tests.

(b) The periodicity in mule yarns has been confirmed by breaking load and twist tests (pp. 69-70) on successive portions of yarn, the twist and strength being abnormally high in those parts which were near the spindle tip throughout each stretch.

(c) The mechanical behaviour of a yarn under the action of the forces produced by oscillating machinery is of great importance in connection with lace making, weaving and knitting. The power of each single thread to withstand such stresses and strains depends upon the amount and regularity of twist. Where the twist is low there is a greater chance of slippage between

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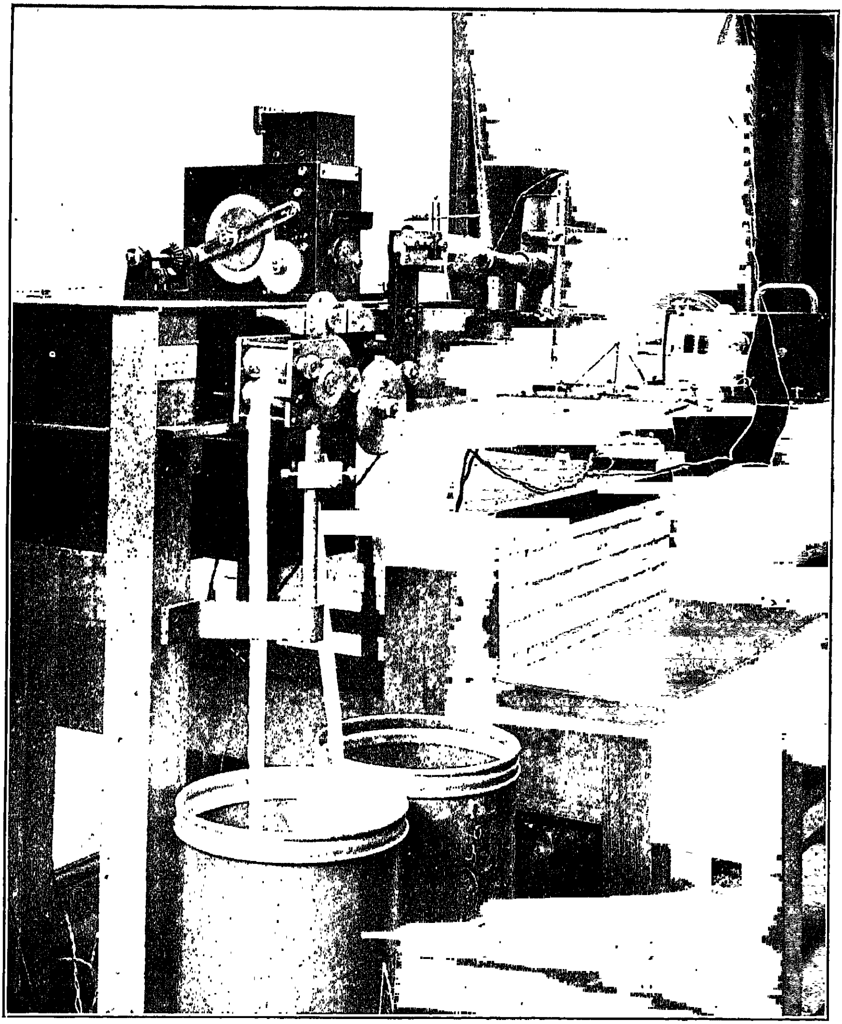
adjacent hairs each time the tension passes through a maximum. On the other hand the twist may be so high that the hairs are interlocked and no slippage is possible. When the greatest tension is less than the breaking load of the specimen the low twisted threads break through the hairs pulling out, while the high twisted ones do not break after many thousands of oscillations. An apparatus called the oscillating stress tester was designed to investigate these effects. When consecutive lengths of mule yarns were mounted in this machine the lower twisted lengths in the greater part of the stretch broke after a few hundred oscillations, while those from near the spindle, with the higher twist, withstood usually 5,000 oscillations without rupture. The periods again coincided with those of the mule stretch, no periodicity being discernible in ring yarns. An abnormally thick place near the spindle tip may cause a displacement of the high twist to some near position where the yarn is thinner.

High Drafting.

The products of several high draft systems have been examined by methods based principally on the tests described above and in addition on comparisons of counts and staple length measurements.

The Casablancas System. This is a 3-line roller system modified by the use of leather aprons round the top and bottom middle rollers in such a way that the nip of the aprons projects into the nip of the front rollers. The cotton used in the investigation was $1\frac{1}{8}$in. to $1\frac{3}{16}$ in. G.M. Memphis, and the yarns compared were spun on the high and ordinary draft systems to 36's twist, the drafts at the ring frame being 19.5 and 7.2 respectively, the roving frame being missed out in the former case.

The tests showed that the Casablancas system can produce a draft of 19.5 in the final operation of spinning rather more efficiently than the ordinary low draft system can do with a roving frame draft of 2.7 and a ring frame draft of 7.2, that is, a total draft of 19.4. In the high



Regularity Tester for measuring the evenness of hank number of slivers and speed frame products.

draft yarn the fibres were distributed a little better and laid straighter than they were in the yarn spun on the low draft system, the difference, however, being slight. The mean length of the fibre was, on the whole, a trifle greater in the Casablancas yarn, as shown by the sorting tests made on the pulled down yarn, this being due either to the more efficient rejection of fly or to more selective treatment in drafting by the aprons. Again the difference was only just perceptible.

The photographic regularity tests showed definitely that the samples of Casablancas yarn examined were the more regular but the difference was hardly significant for trade purposes. In all other respects, strength, counts, and twist per inch, the two yarns had identical properties.

High draft system having top middle roller of wood with steel arbour and leather cover. A similar comparison of high and low draft yarns has been made, using a 3-line roller system, the high draft top middle roller being of wood having a steel arbour and leather cover. The cotton was Egyptian and in spinning 36's all the speed frames were employed, the low draft yarn being spun from 8.5-hank double roving with a draft of 8.4 and the high draft from 3.5 hank double roving with a draft of 20.6. Yarn of 50's count was also spun from 6-hank double roving with a draft of 16.6 and from 6-hank double roving which had been prepared from 0.68-hank slubbing doubled with a draft at the roving frame of 17.6, leaving out the intermediate.

The photographic tests of the diameter under compression indicated that the low draft 36's yarn was slightly more regular than the high draft yarn, but the mean values for breaking load, twist per inch, counts and staple length of cotton for all the 36's yarn were, however, identical. There is no discrepancy in these statements because in a yarn which is slightly less regular than another it is quite possible for the high values of breaking load, twists, and counts to compensate for low values so as to give the same averages as a more level

yarn. Of the 50's yarns the breaking load tests showed that the yarn spun without the intermediate was the stronger but less regular. The greater strength was probably due to the slightly higher number of turns per inch and slightly lower counts, such differences being attributable to small variations in spinning which inevitably arise from differences in the methods of high and low drafting. In all cases, however, the differences are so small that for trade purposes they are insignificant.

Cesoni-Lirussi System. A comparison of the above two sets of high draft yarns, 36's, with 36's spun on the high draft Cesoni-Lirussi system has been made, the draft at the ring frame in the last case being 14.4, the 36's being spun direct from 5-hank double intermediate. Again, for trade purposes, the small differences in irregularity disclosed in all the tests made are insignificant.

Advantage of light top-middle roller. Further investigations have been made on the regularity of high and low draft yarns and the effect of changing the weight of the top-middle roller from 8 ozs. to $3\frac{3}{4}$ ozs. The yarns spun were 20's with 19.6 turns per inch both from $1\frac{1}{2}$ hank intermediate with a draft of 13.3 and from $3\frac{1}{2}$-hank roving with a draft of 5.7. The use of a light top-middle roller was in all cases slightly beneficial, the yarn being slightly stronger and more regular. The introduction of a leather band round the back and middle bottom rollers did not appear to affect the regularity of the yarns.

Platt Bros. & Co.'s Ltd. (C.S. & L.) System. As a further contribution to the general drafting problem a comparison has been made of low draft yarn with yarns spun on the Casablancas system and with Platt Bros. & Co.'s Ltd. (C.S. & L.) patent roller arrangement for long draft yarns. The raw cotton for all the yarns was Sakel, grade good to fine, staple extra fine $1\frac{7}{16}$ in. to $1\frac{1}{2}$in., and up to the end of the intermediate process the treatment of the cotton was the same for each yarn. The low draft

yarn was spun from 7-hank double roving, the draft at the ring frame being 11.6; the Casablancas and Platt's yarns from $3\frac{1}{2}$-hank double intermediate with ring frame drafts of 23.3 and 21.6 respectively, the same intermediate bobbins being used for all the spinnings.

It was found that (a) the Casablancas yarn was slightly finer than the other yarns; (b) the low draft yarn had a slightly higher twist than the other two yarns; (c) the staple length of the cotton in the high draft yarns was greater than that in the low draft yarns; (d) as judged by the tensile tests, the low draft and Platt's yarns were equally strong, and both stronger than the Casablancas, Platt's yarn being the least variable; (e) whilst on the photographic tests for thickness under compression the Casablancas and low draft yarns were equally regular, but the Platt's yarn was less regular. The differences were so small in all cases that for trade purposes the yarns may be regarded as equally good.

With these results, as in the examination of other systems which produce yarns of equal quality, the main consideration therefore becomes one of unbiassed judgment as to the efficiency and practicability (including the questions of cleanliness and replacements) of the various systems. This remark applies to all the work which has been completed on high and low draft yarns.

The work has been extended to four other high draft systems and in each case a complete examination has been made of the card room products leading up to the final spinnings. Comparisons of six yarns, 38's with ring frame drafts of 8.2, 13 and 26, and 52's with drafts of 10.3, 17 and 34 have been made, using the same intermediate bobbins. The differences in the qualities of these yarns were insignificant for trade purposes.

In the last series, tests were also made of the regularity of the card room products using the sliver and roving regularity tester to obtain a continuous record of their thickness under slight compression, with the following results:—

Sample	Card	Combed	1st Head	2nd Head	3rd Head
Irregularity ...	4.57%	5.90%	4.19%	3.89%	3.45%

There is a general decrease of irregularity in thickness under compression from card to last drawing; the percentage figure for the card sliver is lower than that for the comber sliver owing to the greater apparent thickness of the card sliver due to non-parallel fibres, and possibly to the piecing during combing, though the hank numbers are the same. In the speed frames the irregularity increases as the following figures show:—

Sample		Slubbing.	Intermediate	Roving.
Irregularity	...	5.3%	7.8%	11.7%

The cohesion tests made on the sliver and roving impact tester (see p. 70) show how this property falls off in the slivers as the degree of parallelisation increases, the hank numbers of the slivers being the same.

Sample.			Cohesion	Sample	Cohesion
Card	...	...	1090	1st Head	234
Comber	...	...	304	2nd „	216
				3rd „	201

Doubled Yarns—Their Regularity and Lustre.

The regularity of doubled yarns has been investigated by means of an adaptation of the photographic regularity tester, the cylindrical bottom shoe being replaced by a suitably mounted glass or metallic fibre. As the folded yarn is drawn beneath the indicator the top shoe of the latter records a flick as each half fold of the doubling twist passes. These are recorded automatically on a strip of bromide paper in the usual way and from the photographs it is possible to determine the mean doubling twist per inch and the variation which exists in any folded yarn. The results have been verified by an alternative method of recording the regularity of yarns involving the use of "wireless" valves. From a consideration of the irregularities present in single yarns, combined with the resulting irregularities of doubling twist, it has been shown that a variation of lustre approximating to about 30 per cent. can arise from irregularities due to spinning and doubling. This value is based upon photometric measurements of the relative lustre of yarns having different doubling twists. The apparent bright-

ness of the yarn is compared with the brightness of a ground glass surface, the illumination of which can be varied in a known manner. Observations of the lustre of doubled yarns lead to the conclusion that the lustre rises as the doubling twist is inserted in the yarn, reaches a maximum value for a certain doubling twist dependent on the singles twist and then decreases with further increase of doubling twist. Measurement of the twist of the singles and the doubling twist which gives the maximum lustre shows that the maximum lustre is obtained when the doubling twist is in accordance with the rule—

Doubling twist=a constant number multiplied by the square root of the resultant counts,

the constant being that used in spinning the singles yarn. Thus for a two-fold yarn, the best doubling twist to obtain maximum lustre is a reverse twist to that of the singles so that in the doubled yarn the fibres lie in the direction of the axis of the folded yarn. When there are considerable variations of singles and doubles twist these conditions may not hold and lustre variations in the woven or knitted fabric consequently arise. The importance of the correct relationship between singles and doubles twist for maximum lustre has been appreciated by the trade.

The photometric results have been confirmed by direct photography. The yarn samples were photographed through a photographic plate which had first been exposed so that the density of the negative shaded uniformly and gradually from black to clear. The photographs show that yarn with the ideal doubling twist can be discerned to a further distance in the shade than its companions which have a lower or higher doubling twist.

Yarn Testing.

A full study has been made of the various methods of yarn testing, and of the machines used, to eliminate errors of measurement and determine the relation of the results obtained by the several methods to each other

and to the properties of the yarn which affect its practical quality.

An instrument scale, divided up according to the deflection due to a hanging weight, may err in use owing to the momentum or over-run of moving parts. This has been shown to be negligible in machines of the deadweight or pendulum type, and conditions have been determined for the maximum safe speed in quicker tests such as the Moscrop.

Instruments are available for testing yarn at all speeds, taking from a small fraction of a second to weeks for the average time of testing and it has been found that the breaking load increases with speed in a regular way, namely one-tenth the deadweight value for a tenfold increase of speed. Thus a piece of yarn which breaks at $12\frac{1}{4}$ ozs. on the standard single thread tester (in 21 seconds) would show a breaking load of $14\frac{1}{4}$ ozs. on the Moscrop tester, but would be broken in about a fortnight by a hanging weight of $6\frac{1}{8}$ ozs. or in an hour by $9\frac{1}{8}$ ozs. No change could be detected in the final extension, so that it is the strain rather than the load that causes rupture. Formulæ have been developed to calculate the time taken to break a specimen in each machine, and thus allow closer comparison between results obtained by different tests.

As yarn is irregular and each thread must break at the weakest place, long specimens must give a lower mean breaking load than short ones. This effect of length has been worked out theoretically and verified by experiment. For a yarn of average variability the decrease is about 6 per cent. when the length is trebled. Long specimens give more regular results and a closer comparison with the lengths of yarn under load in such operations as winding and weaving.

The relation between the strength of skeins and of single threads has also been worked out. In the ordinary lea test the threads support each other to a variable extent, the later portion of the load is without useful meaning and can be exaggerated by increased speed or, either accidently or deliberately, by the way the lea is

placed on the hooks. The advantages of the test in regularity and sampling may be secured by testing smaller skeins, say quarter-leas, placed on the hooks as a regular band, the result then bearing a known relation to the strength and regularity of the threads.

A study of industrial processes shows that extensibility of yarn is a quality at least as important as breaking load. An autographic machine has been adopted and developed to trace extension against load in a steady test up to Moscrop speeds or in any cycle of tension. Such traces give valuable information about the nature of the extension and of the rupture, recovery from strain and time effects.

As a rapid routine test, however, the ballistic test for work of rupture stands alone. The instrument (p. 70) is essentially a heavy pendulum which breaks the attached specimen by direct tension at the bottom of its swing. The result is a combined measure of breaking load and extension in a quick break, the best index of practical value that any single figure can give. A lea of yarn is mounted for the ballistic test as quickly as on the lea tester, broken much more quickly and gives a figure which is the true sum of the strengths of the threads. The result is therefore more regular than that of the lea test and different numbers of threads can be accurately compared.

Both the strength and extension of yarn increase with humidity up to 80 per cent. relative humidity (80 R.H.). As a correction for such tests, the extent of these changes in warp yarn may be taken as 3.7 per cent. of the breaking load and 7.1 per cent. of the extension at 70 R.H. for an increase of 10 R.H. These figures indicate the effect of atmospheric humidity in strengthening yarn under tension during processes such as winding.

Reference has already been made to the value of testing yarns under oscillating stresses and the sensitiveness of the test to local variations in twist in the specimen. In a recent research the oscillating stress tester has been modified so as to provide polished steel surfaces against which the yarn is rubbed. The aim in

this work was not so much to devise a standard instrument with which to test for resistance to abrasion but rather to learn how to interpret the results of wearing tests. The conclusion drawn is that it is not advisable to take the average of the numbers of rubs resisted by the specimens as an indication of the quality of the yarn, for this gives undue prominence to the most resistant samples. A better indication has been obtained by using more suitable statistical methods.

Yarn Conditioning.

A detailed study has been made of the dipping process. The absorption of water is governed by two factors, time of immersion and depth and the briefest possible immersion will result in as large an absorption as may be desired provided the depth is sufficient. The customary method of shallow immersion for several minutes is not, therefore, the best method of dipping yarns. It is much better to dip as rapidly as possible to a suitable depth.

The distribution of the water among the different bobbins of yarn in a skip has also been examined. The bottom layers are much moister than the top layers, owing to (a) their greater depth of immersion, (b) the drainage which occurs subsequent to dipping, and (c) the smaller loss by evaporation at the bottom than at the top. To cure this unevenness it is suggested that skips should be dipped upside down and re-inverted immediately after dipping. This inversion has been tested in actual mill practice and shown to result in very even conditioning.

The brown staining of yarns after conditioning (or wet doubling) is often due to the action of bacteria in the water and can be prevented to a large extent by adding one pint of commercial formalin to every 60 gallons of the conditioning water. The new method of dipping also reduces the risk of staining to a minimum, since it obviates the excessive dampness in the bottom layers of the skips.

Spinning Tests on Empire and other Cottons.

The cotton grower would be greatly helped by some

means of discovering as quickly as possible whether any particular type experimentally cultivated is worth persevering with, or in what respects it must be improved. The Association has therefore undertaken to supervise spinning tests for the Empire Cotton Growing Corporation, in order to give assistance, wherever possible, to the agricultural departments of our Colonies and Dominions. Tests have also been carried out on samples furnished by the British Cotton Growing Association.

During the two years of this work, nearly two hundred samples have been tested, comprising cottons from almost every corner of the Empire. The African colonies have been responsible for the largest number, however, and in the case of the Uganda cottons the work has contributed directly towards the selection of the Nyassaland Upland strain N. 17, which is now being distributed all over the Protectorate. Those from South Africa were tested with a view to assisting in the the selection of a cotton reasonably immune from "jassid" disease; whilst on the Queensland cottons, the work has been done in collaboration with the resident Director of cotton culture, who is making an attempt to settle the advisability of ratooning in that particular cotton area. A test was also done on the product of a ratooning experiment at the Rufiji station, Tanganyika, and samples tested recently have come from the Sudan (Colombia, Webber, Gendettu, etc.), Kenya, Tanganyika, New Guinea, Nigeria and Cyprus (Sunbeam, Hartsville, Allen's Long Staple, etc.).

Tests have also been carried out for the Egyptian Ministry of Agriculture on cotton produced by the States Domains Administration, Cairo, and the staff of the plant breeding station at Giza. The object of the States Domains is the propagation of pure seed and samples of the various cottons are tested each year by the Association. Up to the present, the assistance given to the plant breeding station has all been in connection with work on ratooning. Tests on the 1924 samples gave some very interesting results which will be available for comparison when the tests on the 1925 crop are completed.

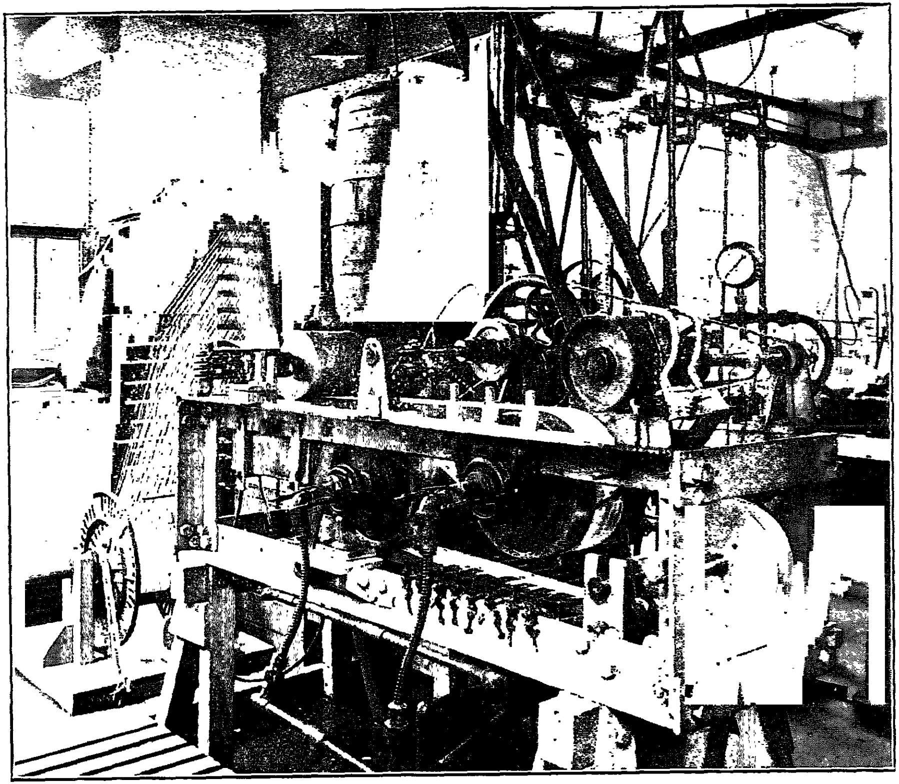
CHAPTER III.

Researches on Sizing.

While the Shirley Laboratories were being built a review of the technical literature on sizing was prepared and a preliminary study was also made of the existing practice in typical tape rooms. The result of this survey was to show that there was then virtually no record of systematic experimental investigation into the process of sizing, while an exact statement of the properties acquired by the yarn in the process was equally lacking. This deficiency as compared with the state of knowledge in other branches of the cotton industry appeared to be due partly to the unwieldy nature of the industrial process, and partly to the difficulty experienced in giving numerical values to the technically important properties of size or of yarn. To obviate the cost and inconvenience of experimenting with mill machinery it appeared necessary to construct a piece of laboratory apparatus for sizing yarn by a process closely similar to that practised in the industry, while at the same time a definite attempt had to be made to find precise measures for the more important properties of the various materials employed. These two lines of attack were the basis of the first programme of laboratory work, while, as a later development, the industrial process has been examined by methods worked out in the laboratory, and an accurate study is being made of the conduct of sizing on the large scale at the present time.

Experimental Sizing in the Laboratory.

In the model tape frame constructed for this work the yarn is drawn through a small hot water jacketed sow box and squeezed by a pair of rollers of the same diameter, material and weight per inch as are used in the trade, while drying is effected by a process substantially similar to industrial cylinder drying. With this



Experimental Tape Frame.

apparatus, experiments have been done which lead to the following conclusions:—

(a) *Varying Twist.* When yarns which are similar in every respect except twist are sized alongside each other the most highly twisted yarn takes up least size.

(b) *Varying Count.* When the same mixture of cotton is spun to different counts and the yarns are sized under the same conditions, more size is taken up by a pound of fine than by a pound of coarse yarn. The comparison has been made in stages over a range of counts from 60's to 8's, and the heavier sizing of the finer yarn always occurs as long as the same twist constant (turns per inch $\div \sqrt{\text{counts}}$) has been employed in spinning the various specimens. The effect is obviously not an effect of twist such as has been noted in paragraph (a) for if fine and coarse yarns were spun with the same number of turns per inch the former would be softer spun and would on that account still further surpass the other in size gathering power.

(c) *Different Types of Cotton.* Yarns of equal counts and twist spun from cottons of different origin take up size to different extents. The difference depends on the fineness of the lint, a coarse staple of high hair weight per centimetre (see p. 2) being stiff, and not easily moulded into yarn form, so that it produces a bulky yarn which takes up size freely. During the course of the work on sizing a definite correlation was established between hair weight and specific volume, a property which expresses the bulkiness of the yarn.

Opinion among manufacturers on the whole is in conflict with the statement made above that finer yarns take up more size than coarse. The explanation is probably to be found in the fact that in industrial practice fine yarns are spun from fine cottons and on this account are more compact and therefore less receptive of size than coarse.

(d) *Nature of size.* The amount of size which any one sort of yarn takes up depends on the composition and

physical behaviour of the size. In dealing with this question it is well to consider that the weighting effect obviously depends both on the percentage of dry solids in the size (the concentration), and on the quantity of paste carried by the yarn. For a normal American yarn of from 20's to 40's counts the percentage of paste (liquid size) taken up by the cotton may range from about 70 when the size is dilute and mobile, up to as much as 200 when the paste is concentrated and viscous. Of two sizes of equal viscosity (see p. 26) that which is the more concentrated has the greater weighting effect; if two sizes are equally concentrated but differ in viscosity, the more viscous is more freely taken up by the yarn; while if, as most commonly happens, viscosity and concentration increase together, the more concentrated, more viscous size has the greater weighting capacity.

(e) *Mechanical Effects.* Increasing the speed of the experimental machine increases slightly the amount of size put on the yarn, a result similar to that observed in industrial practice. Doubling the pressure of the squeezing roller reduces by about one-tenth the amount of size taken by the yarn, while a modification of the roller surface by placing a thin cotton fent over its flannel cover is sufficient to reduce by one-third the amount of size applied.

(f) *Microscopic Examination of Sized Yarn.* When sized cotton yarn is suitably embedded and sectioned the presence of size is made clearly evident under the microscope by the dark blue colour which the starch assumes when the sections are stained with iodine. In examining such sections it is exceedingly difficult to observe the limits to which the size has penetrated into the yarn unless the illumination is so arranged that the outline of the unstained cotton almost disappears into the bright background, leaving the stained starch to be seen by virtue of its colour. When these conditions are fulfilled it is found that in many preparations of yarn sized in the mill the size has left a core of cotton along the axis of the yarn unwetted, and a sharp frontier is observable at the

limit to which the yarn has been invaded by size. In other sized yarns penetration is complete, while the majority of the experimentally sized yarns show examples of both types of section. By suitable means it is possible to give a numerical value to the extent to which any yarn has been penetrated by size, and in this way it has been found, for example, that the depth of penetration is very little affected by the viscosity of the size.

(g) *Penetration of Size into the Yarn.* Penetration of size (as distinct from the amount taken up) is greater when a cotton-faced squeezing roller is used than when bare flannel is employed, while an increase of the pressure exerted by the roller drives the size deeper, so that in experiments where three times the normal pressure was applied size was found throughout the yarn. A second passage through the squeezing rollers increases the depth of penetration into an imperfectly wetted yarn. In yarn sized in the laboratory an unwetted core is most frequently found in yarns of higher counts spun from fine cottons, and it is such material which provides the rather rare examples of imperfect penetration obtained from industrially sized warps. There is as yet no evidence that any practical importance attaches to the degree of penetration of size into warp yarns.

(h) *The Physical Nature of the Process of Tape Sizing.* The foregoing investigation enables a picture to be drawn of the process of tape sizing, in which each end of warp is seen to enter the size and to drag with it a sheath of paste which barely enters the thread. On encountering the squeezing roller, this sheath is to some extent removed as it passes through the region of greatest pressure, and the removal is the more complete the less the viscosity of the size and the greater the weight of the squeezing roller, with the result that the sizing is lighter. Once past this point the quantity of the size on the yarn is fixed though there is some evidence that the paste re-distributes itself in the yarn during the relatively slow process of drying on the heated cylinders.

Determination of the Properties of Size.

An efficient size mixture is one which can be readily applied by the normal machinery to the warp for which it is prepared, and which on drying confers the desired properties on the yarn. The properties of the materials used in the preparation of size can thus be considered either in their relation to the behaviour of the paste, or as bearing on the character of the sized warp.

(a) *The Viscosity of Starch Paste* (*Size*). The viscosity of a liquid gives a measure of the force which is required to maintain it in steady motion. For ordinary liquids the rate of flow through a narrow channel is proportional to the force applied to the liquid, and for such liquids the viscosity can be determined by one measurement such as that of the rate of flow of the liquid under a known head through a standard tube.

Experiments on hot starch pastes showed them to be very different from ordinary liquids in that their rate of flow is not proportional to the driving force, since the viscosity appears to decrease as the driving pressure increases. The published work on this subject is in need of some revision, and a more accurate account of the scientific side of the question will be put forward shortly. Owing to difficulties of interpretation it has not been possible so far to apply the work in the study of industrial operations, but its importance can hardly be doubted when it is realised that of two starch pastes which appear equally viscous at low rates of flow, one may assume a viscosity one hundredth of its original value when driven by a tenfold force, while the other maintains the same consistency under the increased force. It seems probable that the suitability of sizing or finishing pastes for their work depends very largely on their behaviour under the heavy pressures employed in these operations.

Apart from these fundamental considerations the published work on starch pastes has shown that all starch preparations decrease in viscosity if they are stored at a high temperature, and that farina is more susceptible to this change than maize or sago. A small change of

concentration has a relatively large effect on the viscosity of size, a point which is shown below to be of considerable practical importance in tape sizing.

(b) *The Wetting Power of Size.* Experiments on this subject showed that raw cotton is capable of being completely wetted by hot size, but the wetting is dependent on the application of mechanical force for the spreading of size over and into cotton yarn. No decided improvement in wetting power is caused by adding to size substances of the group of which cyclohexanol (sold as "hexalin" or "sextol") is typical, while soap fails to produce any effect in the presence of the starch. The conclusion is drawn that thorough wetting of cotton by size can best be effected by working as near to the boiling point as possible, and by taking care that the squeezing roller exerts effective pressure on the wet yarn. This was confirmed by the experimental work with the laboratory tape frame (see above). In addition, there is evidence that imperfect wetting with consequent inadequate attachment of the size to the cotton is a cause of the dusting of size which is sometimes troublesome in weaving.

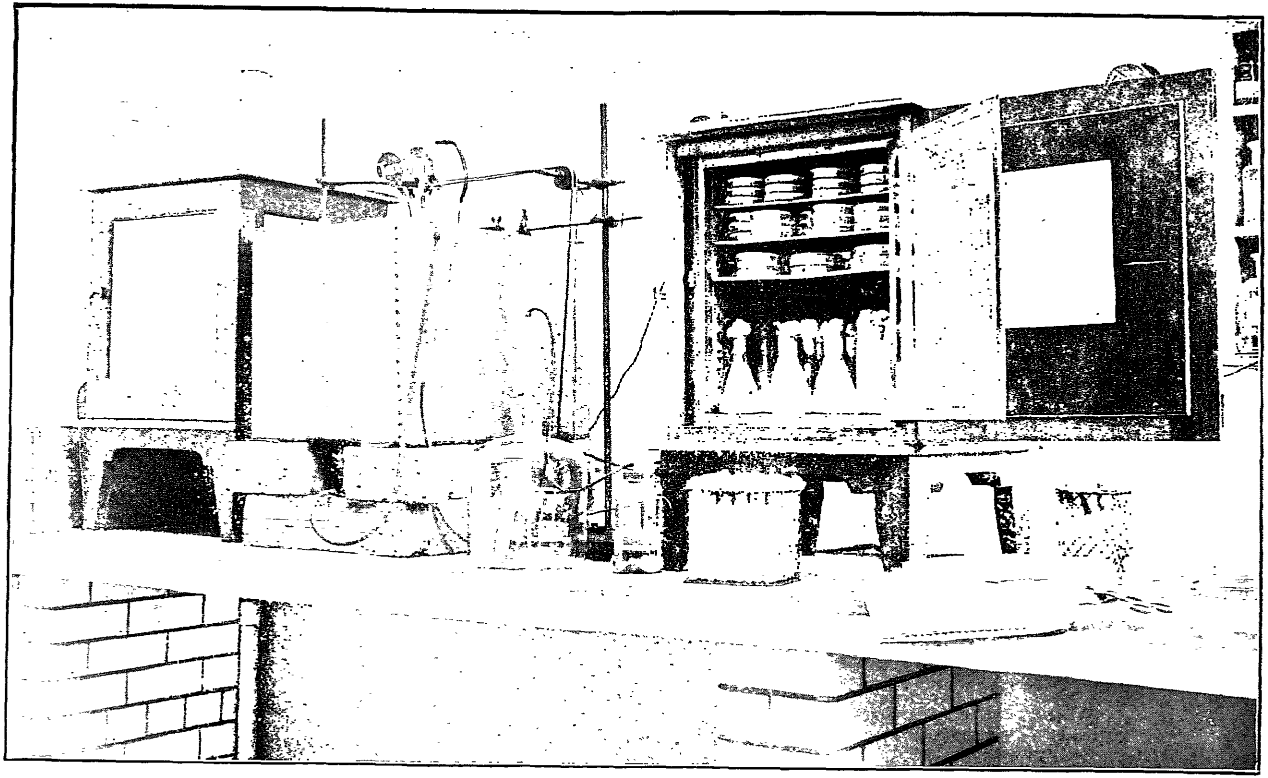
(c) *The Absorption of Water by Dried Starch.* Starch pastes have been evaporated to dryness on sheets of ferro-type plate, or polished brass, and the transparent films so obtained used in experiments on the capacity of size for absorbing water, as well as for measurements of the specific mechanical strength of starch itself. Starch so dried is found to absorb water in much the same way as cotton, the amount taken up, however, being about double, so that sized yarn contains a larger proportion of water to solid matter than does unsized cotton exposed in air of the same humidity. The lag between the absorption of water and its evaporation is greater for starch than for cotton, so that in sized material the water content depends to a more marked extent on the previous treatment than is the case with raw cotton. The capacity of starch for absorbing water is modified by change of temperature in much the same way as is that of cotton.

When deliquescent chlorides are present in starch or sized yarn the amount of water taken up at any state of the atmosphere is less than the sum of the quantities which would be present in the starch, cotton, and deliquescent salt if each were exposed separately. It is at present impossible to account satisfactorily for the favourable mechanical effects produced by these constituents of heavy size mixtures.

(d) *The Mechanical Nature of Dried Starch.* Starch films have tensile properties similar to those of ductile metals and there is apparently little difference in this respect between one starch and another. Drastic chemical treatment renders the starch brittle, while alkalis or soap produce similar effects, though in the mill soap is used with the intention of keeping the size soft. Brittle films are also produced when an excess of a hard fat such as tallow is introduced, the deterioration in flexibility becoming marked when more than about five per cent of fat is present. These observations suggest that excess of fat may give rise to the dusting of size which is troublesome in some mills, and this is borne out by observations in the laboratory.

A Quantitive Study of Industrial Sizing.

Two memoirs have dealt with observations made during the course of sizing in the mills of members of the Association. The earlier paper records the sequence of concentration changes in the sow boxes of a number of tape frames engaged on light sizing, and shows how the observed fluctuations in the composition of the size are reflected in parallel irregularities in the weighting of the warps. In exactly the same way as in laboratory sizing accidental rise or fall in the concentration of the size is accompanied by corresponding changes in its viscosity, with consequent increase or decrease in the extent to which the paste is taken up. The effect of a change of concentration is therefore twofold, altering both the amount of paste carried by the yarn and the weighting value of what is taken up.



Apparatus used for testing mildew antiseptics.

In the second paper it is shown that these fluctuations arise from the inevitable condensation which occurs when open steam is employed to heat size in a freely exposed sow box or beck. This condensation can be represented as a steady inflow of water proportional to the nearly constant loss of heat by radiation and conduction, and as long as the machine is running steadily so that size is used up and replaced at a constant rate, the concentration of size in the sow box attains a steady working value. Serious irregularity, however, follows when for any reason the supply of size is interrupted for an appreciable time, or, what amounts to the same thing, when sizing is interrupted on account of difficulty with the warp. Faulty control of the mixing also has its effects, again dependent on irregularity of concentration, and in the published figures it is shown that the weights of a series of dhooties may vary as much as ten per cent. on this account.

No attempt has been made in these papers to point out remedies, which must depend to a large extent on engineering practice such as the supply of reliable automatic size supply valves, the use of dry steam, and where possible the provision of a heated jacket for the size box so as to minimise the condensation there. The result of the work at this stage is to emphasise the supreme importance of maintaining constant concentration in order that goods may be evenly sized, and to suggest that it is worth a considerable amount of trouble to ensure that mixings are accurately made up, and are used uncontaminated by size residues of differing concentrations in sow box or storage beck. In this connection it may perhaps be suggested that it would be advantageous if more facilities were available for completely emptying all vessels in which size is prepared, stored, or used.

Sizing and the Mildew Problem.

Unbleached cotton contains sufficient food in the form of nitrogenous material, non-cellulosic carbohydrates and soluble mineral salts to support the growth of all the lowly

forms of vegetable life (fungi) which are comprised in the general term "mildew," and it is well known that yarn stored at a suitable temperature in the presence of sufficient moisture is rapidly contaminated with considerable growths of moulds of various types. When, as in sizing, the yarn is treated with starch paste, additional food is provided for such fungi, so that a sized warp or piece of grey cloth is an ideal medium for mildew growth. In a review of the origin and incidence of mildew in the cotton industry, it was shown that raw cotton is already infected in the field with the spores of common mildew fungi, and that this infection must persist right through to the grey cloth. Since the infection is always present both in the cotton and in the atmosphere of the mill and the food substances are always available it is necessary to ensure that no opportunity is given for this very persistent and damaging form of vegetation to establish itself. The least complicated means for controlling mildew is to ensure that the goods (yarn or cloth) are never allowed to lie in storage when containing more than a relatively small amount of moisture (say a total of seven per cent.), for the lower the proportion of water present, the longer the goods will remain free from mildew growth. It is, however, rarely practicable for the manufacturer and packer to ensure such a condition in heavily sized goods.

The Fungi Responsible for Mildew. Mildew may be caused by many types of mould fungi, and more than sixty species have been isolated from mildewed goods sent in by members for examination. These fungi react differently to environmental conditions; as for example, to temperature, moisture content of the material, and to slight variations in the acidity or alkalinity of the size or finish, whilst antiseptics all affect their growth in varying degrees. It is impossible, therefore, to predict from the behaviour of any one species the probable behaviour of even a majority of those which may occur. To overcome this, eight of the many species which have been isolated have been selected as representative for experi-

mental purposes, whilst others have been used for special purposes and extended tests.

The Relative Liability of Different Sizing and Finishing Materials. The substances commonly used in sizing and finishing have been examined for their relative liability to mildew. The flours, for example wheat, rice, and cassava, are most liable, and the dextrins little less so. Farina, sago, and tapioca (cassava) starches are least favourable to the growth of moulds, whilst maize, wheat, and rice starches, gum arabic and gum tragacanth form an intermediate group. In general, fermentation decreases the liability of wheat flours to develop mildew, the growth of some fungi being inhibited or very greatly diminished, but that of others is affected little or not at all. Whatever the period of fermentation, neutralisation of the steeped flour or removal by washing of the acids formed during the process increases its liability to about that of the fresh flour. Steeping with zinc chloride also reduces the liability, but again some species are affected much more than others and if the zinc chloride be removed by washing the liability again rises to that of the unsteeped flour.

The Use of Antiseptics. It is evident that to prevent the development of mildew under the conditions of storage, shipment, and subsequent handling of grey cloth, the most effective means—control of the moisture content—is an ideal which is difficult to attain. Consequently the discovery of antiseptics which may be added to the size mixing or finishing paste without detriment to the feel or appearance of the material and which inhibit the growth of the fungi under such conditions as may arise is a problem of considerable importance. An examination has been made of the relative value of the antiseptics commonly used in the trade, and a number of other substances have been tested.

The restrictions imposed by practical considerations exclude a number of the most poisonous substances which might be suggested, as for general use the antiseptic

must not be volatile in steam, and should be colourless, odourless and non-poisonous to human beings.

Two substances—thallium carbonate and para-nitrophenol—have proved very promising. The first is an expensive substance, not yet produced on a commercial scale, but the relatively small amount required to prevent mildew growth brings its cost as a sizing ingredient down to that of zinc chloride, whilst its admixture with cheaper antiseptics which will effect still further saving would seem possible. Para-nitrophenol is very effective so long as the size mixture is faintly acid in reaction, but is open to the objection that when the mixing is neutral or faintly alkaline a yellow tinge develops which may prove objectionable. Several other substances appear promising from the preliminary tests, and various mixtures are being examined to overcome the special resistance to particular antiseptics which is characteristic of some mildew organisms.

Tensile Properties of Sized Yarn.

In pure sizing, yarn is sized so that it may withstand the bending, rubbing and jerking to which it will be subjected in the loom. The usual strength tests need, therefore, to be supplemented by others designed to assess the resistance of the yarn to these operations if a proper understanding of the effects of sizing is to be reached.

The oscillating stress tester (p. 70) is one instrument which has been applied to this question. The sized yarn is tested under repeated variations of tension, that is under conditions similar to those which may be expected to occur in warp threads on the loom. Sizing is found greatly to enhance the resistance to oscillating tensions but in the cases examined the inference is drawn that the differences in the extent to which this property is conferred by different size mixings are slight compared with variations due to inherent differences between samples of yarn of reputed equality.

Measurements of extensions produced in sized and unsized yarns by such oscillations of tension exhibit a

striking difference which may be interpreted as indicating a cementing action of the size, and the apparent equality of different sizings is explained on the assumption that in all cases the cementing action is sufficiently complete. The increased resistance to the deteriorating effect of oscillations of tension which results from sizing is shown to be accompanied by a reduction in another desirable quality known as the "ultimate extension" of the yarn at break.

Another test is made on bands of yarn to assess more rapidly the degree to which the size protects the yarn against combined rubbing, bending and stretching (p. 71). The resistance varies with the quality of the raw yarn, the proportion of size and the composition thereof but the relation between the results and loom breakages is still under investigation (p. 39). Increase of atmospheric humidity, and to a less extent temperature, increases the durability of yarn to the wear imposed by this test.

Sized yarn is affected by humidity in quite a different way from the unsized material. The strength is greatest between 70 and 80 per cent. relative humidity (R.H.); it is very little affected below 70 R.H., but falls by about 10 per cent. under wet conditions. On the other hand, the extension is extremely sensitive, increasing by 20 per cent. between 70 and 80 R.H. Heavily sized yarns are more affected by humidity than pure sized goods.

A full investigation at all humidities of four types of sized yarn and the same unsized and a knowledge of the effects of humidity on cotton hairs and starch films have made the whole question of yarn strength much clearer. The tensile properties of a yarn sized and unsized are almost identical in the wet state. The increases of strength due to wetting and to sizing are closely related, both being greater for shorter staples, softer twist, or any cause which allows slippage rather than a snap when the yarn breaks. Sizing greatly diminishes the extensibility, which is restored towards that of the unsized yarn as the humidity increases. Definite differences in

strength and extensibility are associated with differences in sizing, but within comparatively narrow limits as the properties of the cotton are the dominating factors.

Analysis of Sized Yarn.

The Determination of Size on Yarn or Cloth. Whatever the method employed for determining size, it is necessary to make allowance for losses sustained by the cotton under the action of the reagents. On this account the determination of size has been carried out by the straightforward process of treating dried weighed samples of material in a flask on a steam bath successively with one per cent. caustic soda for an hour, one half of one per cent. hydrochloric acid for an hour and distilled water for half an hour, washing after each treatment. The samples are then dried at 110° C. and weighed, the loss indicating the amount of size. In the event of the size containing china clay it is necessary finally to ignite the dried desized cotton, and to deduct the weight of ash from the final dry weight before calculating the loss of size. The loss of weight which occurs as a result of treating unsized raw cotton by the above process is about 6 per cent. for Egyptian cotton or 4 per cent. for American. Where the raw material is available this correction is always ascertained by an actual extraction, but in other cases an estimate has to be made as to the contribution of the cotton itself to the loss on extraction, and there is a possible error of one unit when the result is expressed as percentage of size to cotton in the finished goods.

With pure sized goods an alternative method may be used. Dried and weighed yarn bundles or cloth squares are extracted with chloroform, dried, steeped in a dilute malt solution at 50° C. to 60° C. for several hours, washed thoroughly, and finally dried at 110° C. The loss in weight, less a correction for the natural wax and soluble constituents of the cotton, gives the amount of size present.

Deliquescents. Directions have been published for the determination of chlorides, magnesium, zinc, and glycerine in sized goods by methods which give trust-

worthy results with conveniently small samples of cloth. The relative humidity of air above solutions of some of these substances has also been measured, in the course of a study of their efficiency as deliquescents (see p. 28).

Softeners. Information as to the amount and nature of the fatty material which has been used in a size mixing is often required, for example when it is desired to reproduce a given feel or appearance as accurately as possible, or when an abnormal result has been obtained during bleaching or finishing. Occasionally, a reference sample of the unsized material is available, but generally, though the origin of the cotton (e.g. whether American or Egyptian) is known, this is not so, and reference data for the amounts and characteristics of the wax normally present in representative American, Egyptian, Indian and other cottons have had to be determined. For this purpose, the methods of extraction have been standardised and micro methods for the analysis of the extracts elaborated, so as to enable a complete examination to be made with the minimum of material, such methods being particularly valuable when, as is so often the case, the amount of material available for examination is small. The values determined in this manner are the acid value—a measure of the free fatty acids in terms of the amount of caustic potash required to neutralise them; the saponification value—a similar measure of both the free acids and the acids combined as fats or waxes; the unsaponifiable material—a measure of the fatty alcohols, hydrocarbons, etc., which do not react with alkalis; the iodine value, which gives a measure of the "drying" properties of an oil; the acetyl value, which measures free hydroxyl groups; and the acetyl value of the unsaponifiable matter, which determines the composition of the unsaponifiable matter in terms of alcohols and hydrocarbons. In addition, melting point is often of value. Whilst these determinations are rarely all of them necessary, each has some special value in the identification of particular ingredients used in the preparation of size mixings.

American, South American, and Egyptian cottons

usually contain about 0.4 per cent of wax, Sea Island samples about 0.5 per cent, and native Indian varieties about 0.35 per cent. These figures may therefore be employed to determine from the total extract from a sized yarn or cloth the amount of fatty material added during sizing, though it must always be remembered that considerable variations from them may occasionally be found, principally in exotic growths. For the waxes from most varieties of cotton, the acid value varies between 20 and 30; the saponification value between 60 and 80, the iodine value between 22 and 25; the unsaponifiable matter between 50 and 60 per cent; and the acetyl value of the unsaponifiable matter between 110 and 120. Values markedly outside this range are rarely encountered save in the case of native Indian cottons, which are characterised by higher acid, saponification, and iodine values and a lower percentage of unsaponifiable matter than other growths (see p. 3).

Comparison of the values quoted above with those characteristic of the more commonly used softeners at once indicates that from a purely qualitative standpoint considerable insight into the nature of the fatty ingredient present in a size mixing may be obtained from the amount and analytical characteristics of the extract from a sized yarn or grey cloth. This usually answers the purpose of the bleacher, who desires to know whether an abnormal result can be traced to the presence of an unsuitable sizing ingredient in the grey cloth. Thus tallow, Japan wax, and castor oil consist essentially of glycerides and are therefore almost completely saponifiable. Their presence thus causes an increased saponification value and a decreased percentage of unsaponifiable matter. In addition, they differ considerably from one another as regards their iodine values, and an extract containing either tallow or castor oil possesses an iodine value not lower, and in the latter case usually considerably higher than that of the corresponding cotton wax, whilst the presence of Japan wax results in a decreased iodine value. Castor oil is readily distinguished from the others by its high acetyl value.

Spermaceti is a true wax, and contains approximately 50 per cent. of unsaponifiable material, so that although its presence in an extract raises the saponification value (except in the case of extracts from certain Indian cottons) the percentage of unsaponifiable material remains virtually unchanged. The unsaponifiable matter of spermaceti has an acetyl value considerably higher than that of the unsaponifiable substances from cotton wax, and by this means its presence may readily be detected. Pure spermaceti has zero iodine value, and an extract containing it should therefore possess an iodine value considerably lower than that of cotton wax. Many samples of crude spermaceti used in the trade, however, contain a proportion of sperm oil, and therefore have variable iodine values which may, in extreme cases, be as high as that of cotton wax. Paraffin wax consists essentially of a mixture of paraffin hydrocarbons, and is therefore readily detected. In admixture with cotton wax it causes a decreased acid value, saponification value, and iodine value, whilst increasing considerably the proportion of unsaponifiable matter, which will possess abnormally low acetyl and iodine values.

From a knowledge of the amount and the analytical characteristics of the extract from a sized yarn or grey cloth, and the proportion of size present, the approximate characteristics of the softener, or mixture of softeners, can be calculated by the use of the mean values which have been published for cotton waxes of different origin, and with greater accuracy when a reference sample of the unsized material is available. The considerations outlined above thus enable the identity of the softener or softeners to be established. The use of mean reference data for the different varieties of cotton is obviously more trustworthy with medium or heavily sized goods, where the amount of softener in the extract is large in comparison with that of the natural wax, than with lightly sized goods, where small divergences from the mean values for the natural wax become more significant.

CHAPTER IV.

Researches on Weaving.

In the five years with which this report is concerned no memoirs have appeared dealing directly with the subject of weaving. It must not be forgotten, however, that the researches on sizing just described have had as their principal aim the preparation of a warp which is less liable to damage during weaving, while the very laborious researches on the spinning and properties—particularly the regularity — of yarn have a direct bearing on improved production of cloth.

In addition to this in the last two years a considerable amount of work has been done directly on weaving, both in mills and in the laboratory. These researches have shown that the subject is a complex one requiring critical and cautious examination of experimental results, and for this reason early publication is inadvisable. The following summary will serve however, to show in what directions progress has been made.

(a) *A Warp Tension Recorder.* A loom has been installed in the Institute and a programme of work dealing with the tension in warp threads is in progress. By means of a specially designed instrument a photographic trace is obtained which shows that the tension in a warp thread when weaving a plain fabric varies in a regular manner and repeats itself every two picks.

For any setting of the loom the sequence of changes of warp tension is quite definite though the actual tension at different parts of the loom cycle varies widely, and a study has been made of the effect of loom adjustment on the magnitude and variability of the tension in the warp yarn.

(b) A statistical investigation is being carried on in a number of mills to ascertain the relative importance of the various causes which operate to reduce the efficiency of the Lancashire loom. In this work the range of inquiry covers the influence on efficiency of such diverse